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LIVESTOCK METHANE CAPTURE AND ELECTRICITY PRODUCTION IN VIETNAM:

Status, feasibility, economics, and potential

THE AILEG PROJECT

CONTRACT NO. EEM-I-00-07-00004-00
TASK ORDER: AID-OAA-TO-11-00041



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Office of Economic Policy
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Prepared by
Bloomberg New Energy Finance
Abt Associates

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DISCLAIMER

The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development (USAID) or the United States Government.

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AILEG	Analysis and Investment for Low-Emission Growth
Capex	Capital expenditure
CDM	Clean Development Mechanism
CER	Certified emission reduction
EU ETS	European Union Emissions Trading System
FAO	Food and Agriculture Organization
GS	Gold Standard
GVN	Government of Vietnam
IRR	Internal rate of return
LCOE	Levelized cost of electricity
MARD	Ministry of Agriculture and Rural Development
Nm³	Normal cubic meter
Opex	Operational expenditure
PoA	Program of activities
SURE	Solutions Using Renewable Energy
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WtE	Waste-to-energy

I. EXECUTIVE SUMMARY

The major findings of the financial assessment of electricity generation from medium to large scale farm production from livestock wastes in Vietnam by the USAID Analysis and Investment for Low-Emission Growth (AILEG) project are summarized below:

- **Livestock management projects generally capture and combust biogas emitted from decaying manure by treating it in biogas digesters (bio-digesters) through anaerobic digestion.**
- **The technology for capture and use of methane from livestock waste is present in Vietnam, but on a larger scale, biogas digestion technology is not yet widely adopted.** There is only one large commercial farm-scale biogas project underway in Vietnam, financed through the Clean Development Mechanism (CDM).
- **Anaerobic digestion is a commercialized and mature technology, but there remains significant potential to scale up with only 0.5 percent farms using household- and farm-scale biogas digesters.**



Methane capture and utilization is currently not widely adopted within the agriculture sector, with less than 0.5 percent penetration. The current household-scale capacity is around 70 MW (0.07GW); however, the total maximum capacity for electricity generation from larger biogas digesters could be as high as 3.0 GW by 2020, of which 0.7 GW would be farm-scale biogas digesters, equivalent to 1,200-1,400 projects.

- **Anaerobic digestion projects can be very capital intensive.** Average investment costs in Europe oscillate around \$4.0-5.0 million/MW of installed electrical capacity for farm-scale biogas projects, but are lower in Southeast Asia: \$2.5-3.7 million/MW for small projects below 1 MW. Because of economies of scale, larger projects can achieve lower capital expenditure (capex) figures: \$1.2-1.3 million/MW for the least expensive projects of 1.5-3.0 MW. The only Vietnam project with published capex cost \$2.2 million for a 2 MW project. The capex for other electricity sources, such as solar, wind, natural gas and coal is \$1-2 million/MW.

- **Farm-scale livestock biogas faces challenges in becoming economically competitive in Vietnam.** Assuming the feedstock is free of charge, a typical farm-scale livestock methane project of 1 MW size has a levelized cost of electricity (LCOE) of around \$69-87 per megawatt-hour (MWh) – higher than the current wholesale electricity price in Vietnam of \$54/MWh. The LCOE range for biogas (without adjusting for resource collection costs for livestock manure) exceeds the average LCOE for solar, wind, biomass, small hydropower, and geothermal in Vietnam. However, if there are feedstock costs, anaerobic digestion projects are unlikely to be economically viable. If the feedstock were to cost \$20/tonne, then the LCOE would be in the range of \$134-151/MWh. Some additional costs could be partly offset by the sale of digestate, a by-product of the anaerobic digestion process. Digestate is a solid, stable, pathogen-free residue, which can be processed to fertilizers or soil conditioners and is currently used on some farms in Vietnam.
- **Financial incentives as well as training and technical support will determine the development of the biogas market.** If the Government of Vietnam (GVN) wants to scale up livestock biogas for electricity generation, then there is a significant need for finance, technical assistance, education, and legal and regulatory support. Financing is needed to close the gap between the LCOE of electricity for farm-scale biogas and the wholesale price of electricity. This could take the form of capital grants/subsidies, feed-in tariffs, or new international climate finance, and the goal should be to try to obtain internal rates of return of 10 percent or more to make private investment attractive. The value of digestate as a fertilizer and soil conditioner is another important financial factor, and it may be important that the GVN help to develop markets for these products.
- **Although there is one CDM livestock project in Vietnam, future financing will not be driven by the CDM given the collapse in certified emission reduction (CER) prices and potential end of the CDM market in 2015.** Because of significant oversupply, our CER projections are €0.39-0.90/tCO₂e until 2020, which will not be sufficient to drive further development. Instead, financing will need to come from other sources such as governments or multilateral organizations in the form of capital grants or feed-in tariffs.
- **There are many significant co-benefits of livestock biogas capture and use, such as rural development and health benefits of improved air quality.**
- **Livestock biogas is specifically identified in Vietnam's Green Growth Strategy.** Biogas technology reduces greenhouse gas emissions in agriculture and is deemed the most environmentally friendly method of disposing of livestock waste.

2. ECONOMIC AND TECHNICAL FEASIBILITY

Livestock management projects can deal with waste in an environmentally friendly manner and use the resulting biogas to produce electricity and heat. A livestock methane project of a typical 1 MW size has a levelized cost of electricity of around \$69-87/Mega Watt-Hour. Anaerobic digestion is a commercialized and mature technology. However, its small scale and therefore high capital expenditure (capex) is the main challenge to its use.

2.1. INTRODUCTION TO LIVESTOCK METHANE CAPTURE

Biogas is a gas produced by anaerobic digestion or fermentation of organic matter such as manure, sewage sludge, and biodegradable waste. Livestock management projects generally capture and combust biogas emitted from decaying manure by storing and treating it in bio-digesters.

Anaerobic digestion is a biological process in which organic biomass is digested by microorganisms in the absence of oxygen to produce biogas. The process generates biogas with a high methane (50-75 percent) and carbon dioxide (25-50 percent) content as well as digestate, a solid, stable, pathogen-free residue, which can be processed to fertilizers or soil conditioners.

Livestock management projects generally capture and combust biogas emitted from decaying manure by storing and treating it in bio-digesters.

Today, manure can be run through an anaerobic digester to produce biogas. Biogas can then be directly burned (incinerated) to produce electricity, heat, or – both in a combined heat and power cycle. Alternatively, biogas can be cleaned up and converted into bio-methane (i.e., gasification). After upgrading through gasification, the final product has similar qualities to natural gas with a methane content of 94 percent. It can then be injected into the natural gas grid.

When anaerobic digestion is deployed on a small scale for one-household biogas is recovered and used for cooking and lighting. Small-scale biogas digesters are typically designed to produce biogas at the household or community level in rural areas. Most commonly used feedstocks include animal manure, kitchen and garden wastes, or toilet products. Typically, bio-digesters are airtight, round, underground chambers in which anaerobic digestion takes place during five weeks up to several months, depending on the local temperatures.

Anaerobic digestion is often considered an environmentally desirable waste management solution. The process removes organic materials as they are converted to methane, while nutrients are conserved in the digestate. The methane is then combusted for energy production. The subsequent product is carbon dioxide, which has a global warming potential that is 21 times lower than that of methane. Thus, anaerobic digestion reduces net greenhouse gas emissions.

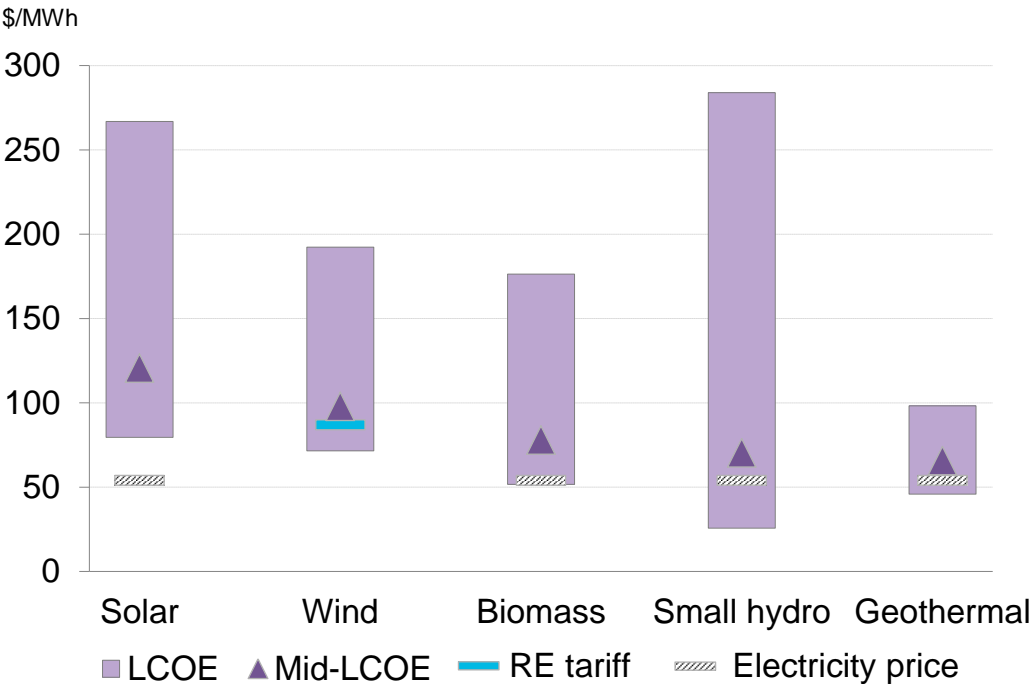
Household-scale installations are unlikely to be a viable commercial investment opportunity due to high initial capital outlay and undefined, inconsistent returns. Medium or large farm-scale installations can potentially offer financial returns sufficient to attract private investors, but high upfront project costs and developer inexperience are likely to present a significant barrier to private investment. **As a result, we focus here on the farm-scale installations and the economics of electricity generation.**

2.2. ECONOMICS OF LIVESTOCK METHANE CAPTURE

2.2.1. RENEWABLE ELECTRICITY GENERATION IN VIETNAM

To better understand the economics of biomass electricity production, it is useful to compare the costs of different electricity production options. Figure I shows the possible range in levelized cost of electricity (LCOE) for selected technologies in the country and compares it to the wholesale electricity price (\$54 per MWh) and the feed-in tariff¹ that exists in the country for wind power (\$87/MWh). The LCOE is defined here as the price of electricity that a project requires to ensure a 15 percent internal rate of return (IRR) for its owners.

FIGURE I: LCOE OF SELECTED RENEWABLE TECHNOLOGIES AT 15 PERCENT IRR



Source: Bloomberg New Energy Finance. Note: RE tariff = feed-in tariff. LCOE = levelized cost of electricity. Electricity price is for wholesale electricity.

¹ A Feed-in-Tariff (FiT) is the price paid per unit by the utility or energy purchaser for the electricity produced.

2.2.2. ANAEROBIC DIGESTION FOR ELECTRICITY PRODUCTION

For the economic analysis in Figure 2 and Figure 3, we assume a 1 MW farm-scale project with two different equity return requirements, either 10 or 15 percent. That is usually equivalent to only one digester though it does depend on the exact design. Some projects have a primary digester that recovers 30 percent of the biogas followed by a secondary digester to recover the rest (this depends on the exact process/technology used). As a comparison, the CDM pipeline consists of farm-scale projects with an average size of 1.8 MW for Southeast Asian livestock projects and 1.6 MW globally.

We have included a comparison with other biomass conversion technologies such as incineration (waste-to-energy or WtE) and gasification. For WtE we have assumed a plant capacity of 30 MW and capex of \$3.5 million/MW; for gasification we have assumed a plant capacity of 10 MW and capex of \$5.5 million/MW. These are average figures that can differ greatly according to the specific project so there is a large range possible for the LCOEs shown.

According to the Bloomberg New Energy Bioenergy Pathways Model, capital repayment costs over the lifetime of an anaerobic digestion project (20 years) are around \$43/MWh in the 10 percent minimum expected return scenario, typically for SE Asia even Vietnam. Capital costs often include land acquisition costs as well as sophisticated equipment such as big above-ground digesters, stirrers, electricity engines, and automatic controls. In a 15 percent minimum expected return scenario, capital repayment costs rise to \$58/MWh. This assumes an average capital cost of \$2.8 million/MW.

FIGURE 2: LCOE AT IRR 10 PERCENT

\$/MWh

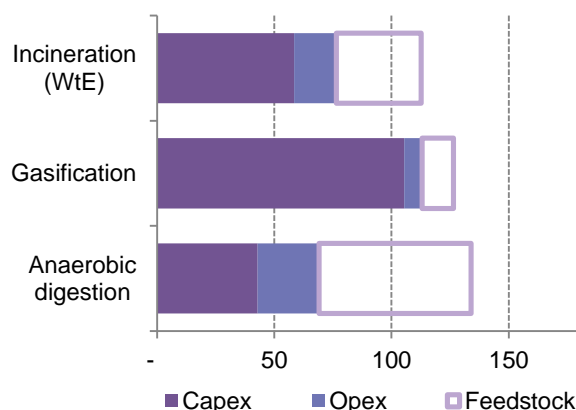
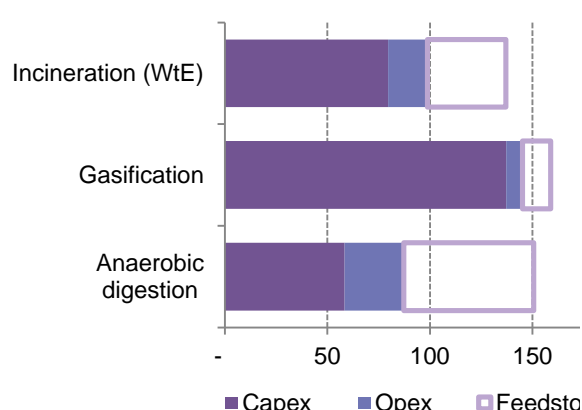


FIGURE 3: LCOE AT IRR 15 PERCENT

\$/MWh



Source: Bloomberg New Energy Finance. Note: An assumption of feedstock cost at \$20/tonne applies to all three technologies. WtE = waste to energy.

Anaerobic digestion projects can be very capital intensive. Average investment costs in Europe oscillate around \$4-5 million/MW of installed electrical capacity; these costs are assumed to be around \$2.8 million/MW in Vietnam (see Figure 4). Average annual operating costs (opex) include labor, operations and maintenance, media, repairs. For an anaerobic digestion project of up to 1 MW capacity, opex are around \$26/MWh in the 10 percent expected return scenario. With a 15 percent expected return, average annual operating expenses go up to \$29/MWh. Anaerobic digestion projects at this scale are rarely economical without subsidies, but electricity prices play an important factor when assessing the cost-effectiveness of projects..

Including both capital and operational costs, the total LCOE for a 1 MW biogas facility would be around \$69-87/MWh in the absence of any feedstock costs for the two IRR scenarios. As comparison, the average retail and wholesale electricity prices are approximately \$70/MWh and \$54/MWh, respectively, which include government subsidies so are below market prices.² Following trends observed in other countries and the country's reliance on fossil fuels, it is expected that wholesale electricity prices will gradually increase over the next ten years. The feedstock costs will usually be zero, as the manure comes straight from the farm and needs to be disposed of. There could also be fees associated with feedstock acquisition. If the feedstock cost were cost \$20/tonne, the LCOE could increase to \$134-151/MWh. Since anaerobic digestion is unlikely to be economically viable at such a high LCOE, it is imperative that feedstock costs be zero or low.

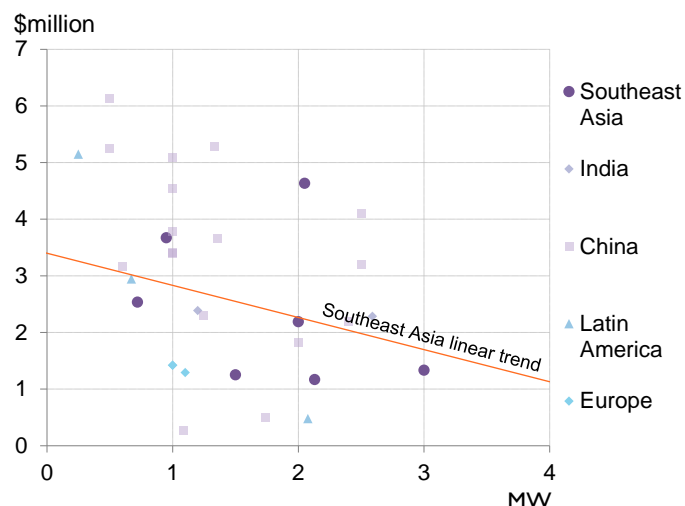
The feedstock costs or operating expenditure can be partly offset by additional revenues from the sale of digestate. The extent to which capital and operating costs can be offset by revenues from electricity, heat, or fertilizer, or the extent to which each project can reduce energy expenditures of interested parties, will depend on the location of the project and on electricity, heat, or gas prices.

These figures can be compared with actual figures from the CDM pipeline, as illustrated in Figure 4 and Figure 5. From these data we can conclude the following.

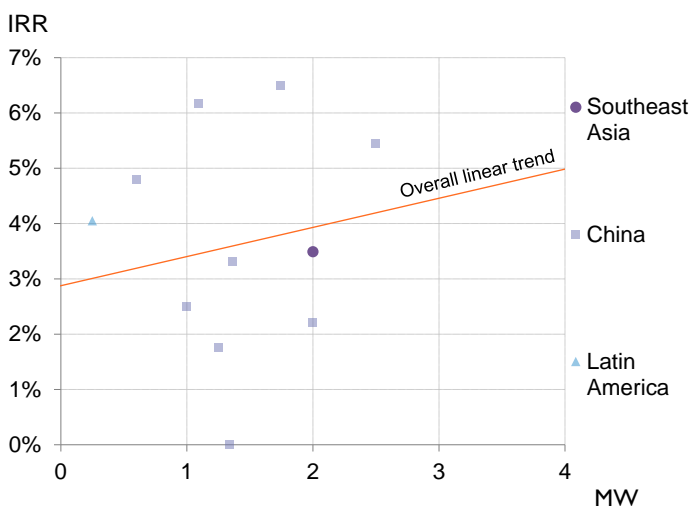
- **Because of economies of scale, capex declines as project size increases** For Thailand, Vietnam, and Singapore, capex is around \$2.5-3.7 million/MW for projects below 1 MW and \$1.2-1.3 million/MW for the least expensive projects for 1.5-3.0 MW. There is currently only one large-scale manure CDM project in Vietnam for a large swine farm consisting of 32 lagoons and using four biogas generators.³ This project lies directly on the approximated trend line at \$2.2 million for a 2 MW project. For the financial analysis we assumed a 1 MW project with a cost of \$2.8 million/MW, based on the typical relationship between capex and project size from around the globe (Figure 4).
- **The IRR increases with project size.** Less data are available for the IRR figures since not all biogas projects in Southeast Asia have disclosed this information. As a result, IRRs can range from 0 percent to 6.5 percent without CER revenues (i.e., certified emission reductions from CDM projects), and the approximated linear trend is not necessarily representative for livestock projects. There is only one published result for Southeast Asia and that is in Vietnam. This shows a 3 percent return without CER revenues, which would increase only marginally with the current carbon price of €0.13/tCO₂e. A €7.50/tCO₂e carbon price would increase the IRR to 26 percent.

² <http://www.bloomberg.com/news/2012-12-21/vietnam-to-raise-average-power-price-by-5-as-costs-rise.html>

³ <http://cdm.unfccc.int/Projects/DB/TUEV-RHEIN1313026895.21/view>

FIGURE 4: UNIT CAPEX COST BY PROJECT SIZE

Source: Bloomberg New Energy Finance. CDM Project Design Documents.

FIGURE 5: PROJECT IRR BY PROJECT SIZE, WITHOUT CER REVENUES

Source: Bloomberg New Energy Finance. CDM Project Design Documents.

2.3. TECHNICAL FEASIBILITY

Anaerobic digestion is a commercialized and mature technology. Although the first anaerobic digester was built in 1859 in India, the technology gained real momentum during World War II, when it was used for treatment of manure in both France and Germany. The European biogas sector has grown rapidly in recent years. Gross electricity production from biogas in Europe rose from 17 TWh in 2006 to more than 29 TWh in 2010. Most of the added capacity came from small and medium-sized, farm-based anaerobic digestion projects.

The variability in associated costs is quite high: costs can vary depending on the size of the unit, design, and additional features. Production costs are also influenced by the type of feedstock used and its energy content and homogeneity. However, because the technology is commercialized, standard designs and off-the-shelf equipment are available. Once the location (which determines electricity, gas prices, and availability of subsidies) and the amount and type of feedstock are decided, the costs and revenues can be estimated more precisely.

Anaerobic digestion is a commercialized and mature technology. The small scale and therefore high capex of these projects is the main challenge to its use.

The product itself is standard as well. Although the amount of methane in biogas can vary depending on the process and feedstock used, some standardized values regarding the efficiency of the process can be assumed. Thermal energy available from methane in biogas is about 6-8 kWh/m³, while 1 kg of cattle manure delivers around 0.04 Nm³ of biogas, and 1 kg of chicken droppings generates about 0.07 Nm³ of biogas.

The average size of an anaerobic digestion project in Europe is around 1.0-1.5 MW. However, farm-based projects can often be smaller, around 0.5-0.8 MW of capacity. Projects in developing countries are often even smaller, 0.2-0.5 MW. Generally, such small projects can involve one digester, buried in the ground, which can serve on average two farms, with two pigs each on average. Because farm size varies (e.g., in terms of land area and number of cattle or pigs), it is difficult to standardize anaerobic digestion projects. Larger projects above 2 MW capacity are possible; however, there are still some scaling issues including land availability, operational and technology feasibility, and feedstock supply.

Sourcing, delivery, and storage of large volumes of wet, low-energy-density feedstock can be expensive. Storage, moreover, is often associated with odors and has low public acceptance. Therefore, it is better the closer the project's location to the source of feedstock. Any benefits in capital cost reductions associated with larger-scale operations are actually offset by lower efficiencies and process disruptions, which often make a case against large-scale anaerobic digestion projects. One solution is building several 1 MW digesters instead of one large one, but in that case capital cost reductions are minimal.

2.3.1. EXAMPLE: CHINA

Rural China is famous for generating energy from small-scale biogas plants, which have been installed since the 1960s. About 17 million household digesters are in place, and the Chinese government is supporting further development with extensive subsidies of 12.5 billion yuan (\$1.7 billion) in order to achieve the target of 62 million new plants by 2020.

China's biogas sector may have started small, but domestic livestock farms and the food industry have also begun to implement medium-sized and large plants. One of the biggest Chinese dairy companies, Inner Mongolia Meng Niu, has invested \$6.2 million in a 1.4 MW plant, which was commissioned in January this year using manure. As the project progresses, the company plans to build 20 further plants on its sites. China has installed about 4,000 industrial-scale biogas plants (100 kW-1.5 MW), and this number is expected to reach 8,000 by 2015 again using manure.

China has been very successful quantitatively, across a multitude of industries, in developing all types of electricity generation biogas and other renewable energy technologies. Because China embraced the CDM process early on, this process has had particular success in the country. As a result, it has been able to build the necessary infrastructure to support this development including technical expertise, financial expertise, and general awareness.

2.3.2. EXAMPLE: VIETNAM

Development of anaerobic digestion in Vietnam has so far been focused on small-scale, low-cost polyethylene biogas digesters. It is estimated that around 30,000 such units for small households having 2-3 pigs have been installed in Vietnam. The total number of anaerobic digesters is much higher, though: around 140,000 for medium-sized households (3+ pigs per household), which with an average size of 0.5 kW would represent a maximum 70 MW of electricity or heat production because of greater methane availability. Vietnam is not faced with significantly different barriers from those of other countries, and it has been proven that small-scale household digesters can be deployed in the country provided the financial incentives are present. Consequently, there is no issue with the technical feasibility of these types of projects in the country. Nevertheless, larger-scale, farm-sized digesters remain rare in Vietnam, and there is only one 2 MW project in the CDM pipeline. Thus, the technical expertise for larger projects has not yet developed to the same scale as in, for example, China.

3. CURRENT STATUS AND FUTURE POTENTIAL

The technology for capture and use of methane from livestock waste is present in Vietnam – mainly on a smaller or medium household scale – but there remains significant potential to scale up the number of commercial or larger household- and farm-scale biogas digesters in the country. On a commercial farm scale, biogas digestion technology is not yet widely adopted, creating a significant opportunity to achieve emission reductions and cost and energy savings in the Vietnamese agricultural sector.

3.1. CURRENT STATUS

Several government-funded programs have emerged as the leading players in the development of livestock methane capture technology in Vietnam. The Vietnam government is working with Dutch, Finnish, and Swedish government and non-government organizations, as well as the Asian Development Bank (ADB) and Nordic Development fund, which are providing financial assistance for capacity building, pilots, and rollout of household- and farm-scale biogas technology in Vietnam with support from the government in terms of FiTs.

The current status of household scale biogas digestion technology in Vietnam is closely linked to an initiative being implemented by the Vietnam Ministry of Agriculture and Rural Development (MARD),^{4,5} in partnership with the Dutch government (through SNV Netherlands Development Organisation), to increase the number of household-scale biogas digesters in the country. Biogas produced on a small scale (average size 11 m³) is used primarily for domestic heating and as a clean fuel for home cooking. Dutch government sources claim that around 140,000 household-scale biogas digesters have been installed in the country to date, more than half of which have been installed since 2007⁶ as part of the MARD initiative (see below for more details).

Vietnam has a large agricultural sector with approximately 27,000 medium- to large-scale livestock farms (more than 300 animals). Methane capture and utilization is currently not widely adopted within the sector, with less than 0.5 percent penetration.⁷ The main reasons for the low development have been the high capital cost, the high interest rates for debt (loans) in Vietnam, limited awareness, and lack of technical expertise. Once the

Vietnam has a large agricultural sector with approximately 27,000 medium- to large-scale livestock farms, but methane capture and utilization has been adopted by less than 0.5 percent.

⁴ <http://www.agroviet.gov.vn/en/Pages/default.aspx>

⁵ <http://www.biogas.org.vn/english/Home.aspx>

⁶ <http://www.snvworld.org/en/sectors/renewable-energy/news/world-energy-award-for-vietnam-biogas-programme>

⁷ http://www.eepmekong.org/main_navigation/document_centre.php?reload (Annex 10)

economics make sense, the other barriers are more likely to be overcome. One other initiative is underway, funded by the Finnish government and Nordic Development Fund, to pilot “plug-flow” biogas digestion and power generation technology at 10 pig farms (ranging from 300-1,500 pigs) across the country. As of January 2013, nine of the pilots have been completed, producing a total of 1,000m³ of biogas production per day.⁸

TABLE 1: KEY ENTITIES CURRENTLY INVOLVED IN LIVESTOCK BIOGAS TECHNOLOGY IN VIETNAM

Funding Providers	Development Agencies	Vietnamese Implementing Entities
Government of the Netherlands	SNV (Netherlands)	MARD
Government of Finland	EEP Mekong	Livestock Production Department
Nordic Development Fund	Stockholm Environment Institute	Biogas Program for the animal husbandry sector in Vietnam

Source: Bloomberg New Energy Finance.

The MARD household program has received a \$95 million loan from the ADB⁹ and is pursuing carbon finance through both the CDM and the Gold Standard, which are two voluntary carbon markets currently trading emission reductions (see Section 4.1.3 for further details). The farm-scale pilot program is being led by SNV and the Stockholm Environment Institute, and funded by the Energy and Environment Partnership – Mekong, a partnership between the Finnish Government and the Nordic Development Fund.¹⁰ The project is being led by SNV, a not-for-profit development organization based in the Netherlands, which also led the household-scale program. SNV is planning to replicate the success of the household program by partnering again with MARD and is aiming to roll out 200 farm-scale biogas digesters over the next five years.¹¹

In addition to the SNV/MARD initiatives, at least one commercial farm-scale biogas project is underway in Vietnam according to CDM project documentation(see Section 4).¹²

One commercial farm-scale biogas project is underway in Vietnam, financed through the CDM.

Solutions Using Renewable Energy

(SURE), a Philippines-based renewable energy developer, has invested in the project to build and operate a 2 MW power plant on a pig farm housing 13,800 sows, located in Binh Duong Province.¹³ The project began operation in late 2011 and is the first of its kind at this scale in Vietnam.

⁸ Ibid.

⁹ <http://www.adb.org/projects/documents/quality-and-safety-enhancement-agricultural-products-and-biogas-development-project-pp>

¹⁰ http://www.eepmekong.org/about_us/eep_overview.php?reload

¹¹ http://www.eepmekong.org/main_navigation/document_centre.php?reload (Annex 10)

¹² <http://cdm.unfccc.int/Projects/DB/TUEV-RHEIN1313026895.21/view>

¹³ <http://sure.com.ph/wordpress/power/biogas-solutions/>

3.2. FUTURE POTENTIAL

3.2.1. METHODOLOGY

To estimate the potential number of projects that could be implemented by utilizing livestock manure in Vietnam, we looked at the current and projected number of livestock in the country and the electricity production that can be achieved. We used the following formula:

$$\text{Number of livestock} \times \text{manure production per year by each livestock} \times \text{MWh of electricity generated by each tonne of manure} / 8760 / \text{capacity factor}$$

The study used UN Food and Agriculture Organization (FAO) statistics for the number of livestock in Vietnam (Table 2). Various sources were reviewed to estimate manure production factors for different types of livestock (Table 3). An average generation factor of 0.33 MWh of electricity generation per tonne of livestock manure and a capacity factor of 80 percent were assumed to convert the total livestock manure available in each year into potential project capacity. The study assumed a flat annual growth rate of 2 percent in the livestock population, extrapolated from historical growth over the past decade.

TABLE 2: NUMBER OF LIVESTOCK ANIMALS IN VIETNAM (IN 2011)

Pigs	Dairy Cattle	Water Buffalo	Goats	Horses	Chickens	Ducks
27,056,000	5,436,600	2,712,000	1,267,800	88,100	225,820	96,780

Source: Bloomberg New Energy Finance. FAO.

TABLE 3: MANURE PRODUCTION FACTORS (TONNES/YR PER ANIMAL)

Pigs	Dairy Cattle	Water Buffalo	Goats	Horses	Chickens	Ducks
0.9	3.2	3.3	0.4	3.7	0.01	0.01

Source: Bloomberg New Energy Finance. Various sources. Dairy cattle were assumed to weigh 500 lbs; "water buffalo were assumed to be equivalent to beef cattle at 750 lbs h; Pigs were estimated at 150-200 pounds.

3.2.2. MARKET SIZE

Given Vietnam's large agriculture sector and low utilization of methane from livestock manure, the country has huge potential to deploy biogas technology for electricity generation. In 2011, Vietnam had 36.6 million livestock, including 27 million pigs, 8.1 million cattle, 1.3 million goats and horses, and 323 million chickens and ducks.

These livestock could produce 133 million tonnes of manure a year, which could generate 18.6 TWh of electricity, or 2.6 GW of project capacity through anaerobic digestion technology (Figure 6). Vietnam's livestock industry has experienced a compound annual growth rate of 2 percent over the past 10 years. If this growth continues over the next five years, the country's livestock industry would be able to provide enough manure for 21.3 TWh of electricity generation (3 GW of project capacity) per year by 2020. This would be 22

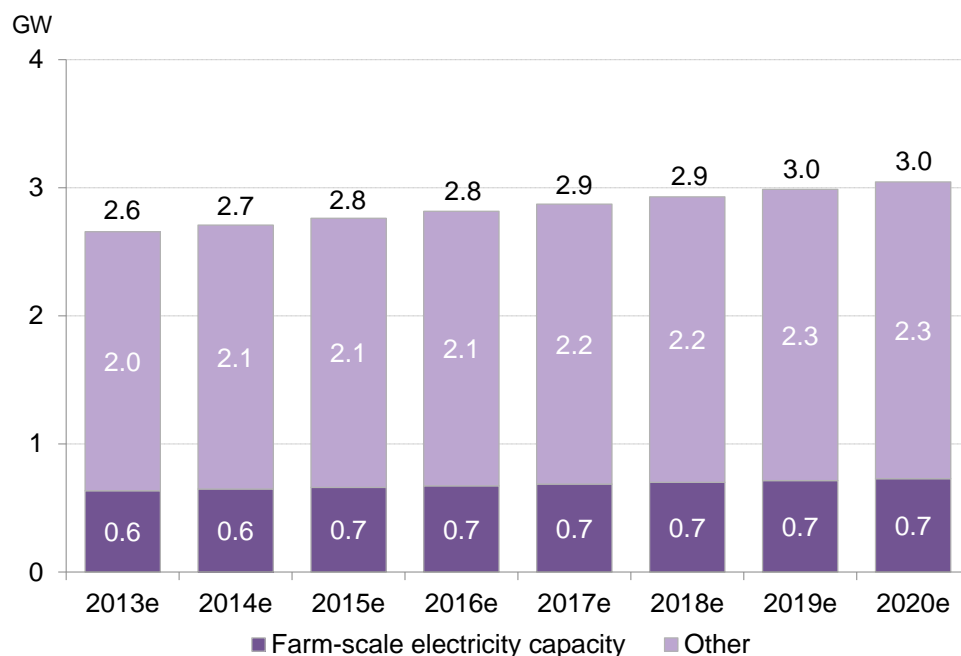
Vietnam has the potential for at least 0.6 GW of farm-scale biogas digesters, the equivalent of 1,200 projects of 0.5 MW. The theoretical maximum capacity is close to 3 GW.

percent of Vietnam's total electricity generation of 97 TWh in 2010. However, this is the maximum potential, which is unlikely to be reached due to the higher returns for investing other renewable energy options (solar and wind) in the country.

Electricity generation is not the only way of deploying anaerobic technology on livestock manure. Cooking, lighting, heating, and other applications are also common in Vietnam. Past experience has shown that the deployment of anaerobic digestion technology on livestock manure for electricity generation has mostly taken place at large-scale farms. Small-scale projects, such as household-scale projects, have primarily been developed for domestic cooking, lighting, and heating.

There are currently 27,000 medium to large-scale livestock farms in Vietnam with at least 300 animals, which could produce 0.6 GW of biogas electricity (Figure 6). Biogas electricity production could grow to 0.7 GW by 2020, assuming the proportion of farm-scale deployment to the total remains constant. Assuming an average size of 0.5 MW per project, this would require establishing 1,200-1,400 projects.

FIGURE 6: POTENTIAL ELECTRICITY GENERATION CAPACITY FROM LIVESTOCK MANURE IN VIETNAM



Source: Bloomberg New Energy Finance. Note: "other" is the non-farm electricity capacity calculated by subtracting the farm-scale electricity capacity from total electricity capacity from livestock manure. E = estimate

3.3. BARRIERS TO GROWTH

There are multiple key barriers to further growth of the biogas sector in Vietnam – technical; financial, legal, and regulatory; and informational.

3.3.1. TECHNICAL BARRIERS

High capital costs can be a barrier in Vietnam. Although small household digesters operating on manure from 10 pigs can cost as little as tens of dollars, more sophisticated, industrial, and larger-scale systems that are common in Europe are capital intensive (\$4-5 million/MW compared to \$1-2 million/MW for solar, wind, gas, and coal powered electricity). European anaerobic digestion plants require a high degree of technical management to ensure consistent power output; in addition, planning, design, and construction require skilled labor.

Lack of experienced and skilled workers in the construction, operation, and maintenance of biogas plants is also delaying the development of biogas electricity in Vietnam. Moreover, access to after-construction service, spare parts, and equipment is limited.

The nature of the technology makes it viable only on a relatively small scale. Scaling problems, arising from significant land requirements, transformation efficiencies, and continuity of the process prevent the technology from operating on a scale larger than a few megawatts.

3.3.2. FINANCIAL, LEGAL, AND REGULATORY NEEDS

Lack of stability and transparency regarding future subsidies is another barrier. Vietnamese farmers will need stable and predictable extension and FiT support from the government, most likely in the form of investment subsidies or production subsidies. Taking the results from the LCOE analysis in Section 2.2.1, an anaerobic digestion project needs to have a revenue stream of at least \$69-87/MWh in order for the project to be economically viable. A feed-in tariff subsidy at this level would enable the development of these projects in the country. However, given the high capital costs for anaerobic digestion and the high cost of debt in the country, it may make more sense to provide an upfront capex subsidy. This should be of sufficient magnitude to reduce the LCOE from \$69-87/MWh to less than \$50/MWh, as this would make the technology competitive with wholesale electricity prices, which are subsidized hence not socially optimal economic or shadow costs. One downside of a capex subsidy is the difficulty of ensuring the quality of the project, as the capex subsidy is an upfront payment rather than a generation payment. It is particularly important for Vietnamese farmers that the offered subsidy provide adequate support for small-scale anaerobic digestion plants and be tailored to their needs. Comprehensive regulatory procedures could enable access to more sources of finance but again market distortions between fossil and renewable fuels compromise open electricity generation market competition in the country. International climate finance can play a role in bridging the finance gap (Section 4.2), but existing carbon market finance is unlikely to catalyze the deployment of this technology.

The value of digestate as a fertilizer and soil conditioner is another important factor. It is essential to develop markets for these products. The government can help build such markets by creating quality standards similar to those set up

Projects can develop quickly once there is an established market for digestate, which the government can stimulate in various ways.

by India and China that would give more credibility to the product.

3.3.3. LACK OF AWARENESS

There is a general lack of knowledge about the anaerobic digestion technology and potential benefits it could bring to the society. Farmers and others in the food supply chain are still unfamiliar with digestate and its uses. There is therefore a need to increase awareness of the value of the products and confidence that they can be used safely within agricultural systems.

Many household anaerobic digesters in Vietnam were actually shut down after several years, as they were not properly maintained and repaired given the lack of extension on best operating practices. Training and education on operation and maintenance of such systems are required.

3.4. PREREQUISITES FOR GROWTH

Vietnam has a large and expanding animal husbandry sector with high potential for biogas generation. Nevertheless, availability of training, technical support, and financial and legal assistance will be decisive in the future growth of the biogas market, and in its implementation on an industrial scale. Of these, good financial incentives and proper technical assistance are paramount to develop the industry.

In 2010, the Vietnamese Biogas Association was established in the form of a social-occupational organization that included individuals, organizations, and voluntary members. Such an organization could play a key role in education and training for the biogas sector by establishing a network of

There is significant potential in Vietnam, but training and technical support as well as financial incentives will determine the future of the biogas market.

scientists, skilled technical staff, and construction workers at the national and community levels. This would allow knowledge sharing about different types of biogas systems and techniques and assist farmers with choosing the optimal solution for their needs, but caution is needed to ensure market competition across different fossil and renewable energy sources.

Training and education on operations and maintenance of such systems are required to prolong the life of anaerobic digestion projects. Education on the seasonality of different feedstocks, their energy content, and their long-term availability is also important.

Introducing industrial-scale anaerobic digestion plants and convincing local farming associations and food industries to implement this technology, will call for significant technical assistance and support. Easy access to spare parts and help with installation are also essential. Better understanding of the financial and economic (social opportunity costs) of alternative options warrants further analysis.

Moreover, if the Government of Vietnam wants to expand the deployment of this technology, then tailored financing mechanisms will need to be developed to increase the number of biogas plants. Government commitment to the sector will lower perceived investor risks and attract both domestic and international investors, thus helping to foster a market for the electricity production from biogas. Note that there is already a small-scale market for heating and cooking with biogas.

4. FINANCING

The economics of a livestock methane capture and utilization project are closely linked to the size and capacity. As stated in Section 2.2, household-scale installations are unlikely to represent a viable commercial investment opportunity due to high initial capital outlay and undefined, inconsistent returns. Farm-scale installations can potentially offer financial returns sufficient to attract private investors when high FiT and capex subsidies exist, but high upfront project costs and developer inexperience are likely to present a significant barrier to private investment. This section explores the various types of financial assistance that may be available to overcome these barriers, either through the carbon markets or targeted climate finance initiatives.

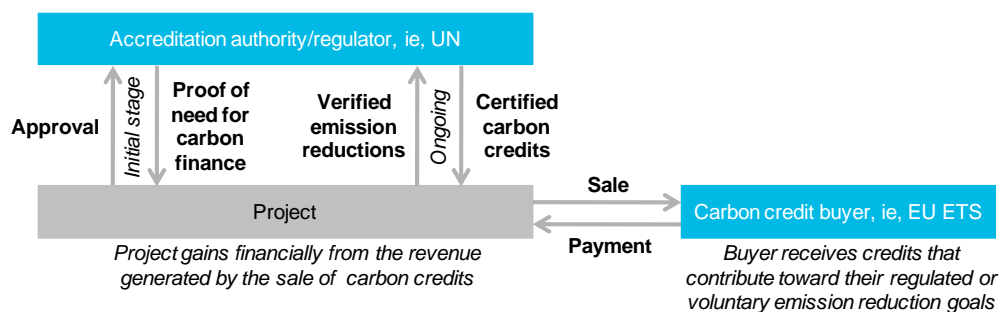
4.1. CARBON FINANCE

Livestock methane capture and use in Vietnam is eligible for “carbon finance” through the UN CDM, or various voluntary offset accreditation schemes.

Livestock methane capture and use is eligible for “carbon finance” through the UN CDM or various voluntary offset accreditation schemes.

Carbon finance offers a long-term revenue stream to a project, providing a boost to estimated returns on investment. A qualifying project receives a stream of carbon credits or “offsets” (certificates representing 1 tonne of reduced emissions) over its lifetime that it can then sell to the various markets around the world that place a value on them (Figure 7).

FIGURE 7: OVERVIEW OF CARBON CREDIT CYCLE—REGULATOR, PROJECT, AND BUYER



Source: Bloomberg New Energy Finance. 2013.

First, a project must gain accreditation to allow it to generate offset credits. This accreditation is given by the United Nations under the CDM or various voluntary emission reduction standard verification organizations, such as the Gold Standard (GS) scheme, the latter of which includes social as well as emission reduction and other environmental verification standards in this voluntary emission market verification system. A project must prove that it results in an overall reduction in emissions from the “business-as-usual” scenario or “baseline,” and also that it is not viable, financially or otherwise, without the assistance achieved through carbon finance.

4.1.1. EMISSIONS BASELINE

For carbon offset projects, the “baseline” or “business-as-usual” scenario is the hypothetical situation that would prevail in the absence of the project. A project qualifies for carbon offsets if the baseline scenario would have resulted in a higher level of greenhouse gas emissions than the project itself. An estimate for the level of emission reductions is calculated using real or hypothetical data, depending on the availability and practicality of gathering data for the project.

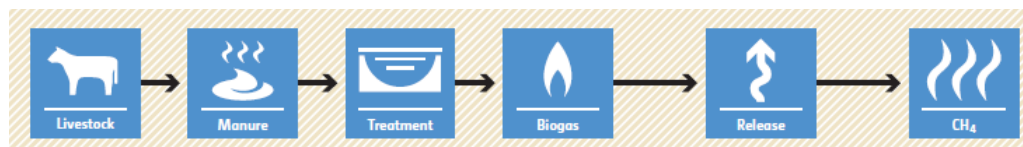
The baseline for livestock methane capture and use has two components:

- Existing manure management system and treatment process (i.e., waste lagoons)
- Existing sources of fuel for heating or power that the project will partially or fully displace

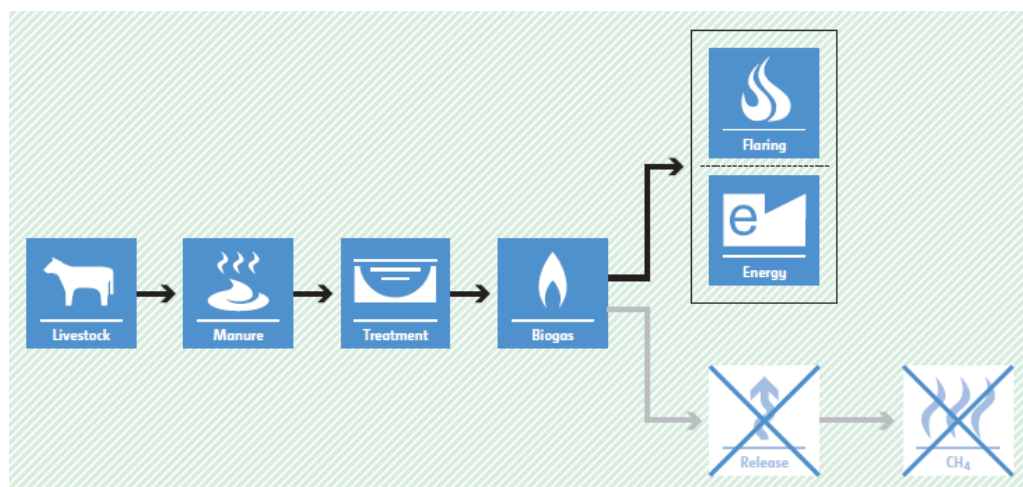
Livestock methane capture and utilization projects generate emission reductions as a result of 1) improving existing manure management systems and reducing methane vapors from uncontained lagoons (Figure 8); and 2) displacing heating fuels or imported electricity with energy generated by the project.

FIGURE 8: EMISSION REDUCTION CONCEPT FOR LIVESTOCK METHANE CAPTURE AND UTILIZATION

Baseline scenario: methane released from livestock manure and biogas unutilized.



Project scenario: methane from livestock manure captured and utilized or flared.



Source: United Nations Framework Convention on Climate Change (UNFCCC).

4.1.2. ADDITIONALITY

To qualify for carbon finance, a project must prove that it is unlikely to come to fruition without the financial support of revenues from the sale of carbon offsets. Additionality is “the justification that a project would face insurmountable barriers without financial support from the carbon market.” If a project is likely to be built and operated in any case, it does not result in an “additional” emission reduction and therefore cannot qualify for carbon offsets.

Additionality is the financial risk/reward assessment that it is assumed all investors use to guide their decision making. A financial justification for additionality is the simple argument that a project does not offer sufficient returns to attract investment, with a benchmark or “hurdle rate” used as a reference for a sufficient return. The hurdle rate can be defined in a number of ways but is usually based on an internal rate of return of alternative investments. Additionality can also be argued based on non-financial barriers, such as technology risk, lack of experience, and adoption of an early-stage technology. These barriers are harder to define than financial returns but can be important considerations for investors.

4.1.3. ACCREDITATION SCHEMES

CDM

The UN Clean Development Mechanism is the world's largest emissions offset scheme with more than 6,000 approved projects and 1.2 billion tonnes of emission reductions issued to date. Overseen by the UN, the CDM is a major component of the international climate policy framework and provides inter-linkage between regional cap-and-trade schemes around the world.

Demand for CERs – each representing 1 tonne of emission reductions – comes mainly from companies covered by cap-and-trade legislation in the European Union and New Zealand emission trading schemes. The Australia carbon pricing mechanism also accepts CERs, and a number of national governments, such as Japan, purchase UN offsets to contribute towards their national emission reductions goals. The CDM market phases out in 2015, with the potential for the UNFCCC renewal.

GOLD STANDARD FOUNDATION

The GS was set up in 2003 by the World Wildlife Fund and a consortium of environmental NGOs to create a recognizable certification standard for carbon offsets from renewable energy and energy efficiency projects. The GS is broadly based on CDM methods, but has more stringent requirements for additionality and requires that projects “positively impact the economy, health, welfare and environment of the local community hosting the project.” There are currently more than 750 GS projects and more than 45 million tonnes of GS offsets have been issued as of early 2013.¹⁴

Demand for GS credits comes mainly from the voluntary market. Voluntary market buyers are likely to value offsets based upon how well they fit with certain advertisement campaigns or corporate social responsibility goals. In addition, consumer awareness can boost the “brand value” of certain voluntary offset accreditation standards. GS is broadly considered to be the benchmark for voluntary offsets, and many project developers therefore choose to invest in GS accreditation in the hope that it will increase the value of the offsets their projects will generate.

A CDM project can also gain GS accreditation if it meets the certification standards. Buyers in compliance markets such as the European Union Emissions Trading System (EU ETS) may be willing to pay a premium for GS CERs if their corporate social responsibility and marketing management strategy justify the additional expense. However, GS accreditation is not recognized by exchanges for CER spot and futures contracts, because of the more complex nature of the verification mechanism, so any premium attached to GS credits is difficult to benchmark.

VERIFIED CARBON STANDARD AND OTHER SCHEMES

In addition to the GS, there are a number of offset accreditation standards that supply credits to the voluntary carbon market. The Verified Carbon Standard¹⁵ is among the largest, with almost 1,000 approved projects and more than 116 million tonnes of credits issued to date. The costs and administrative expense for projects differs among various voluntary offset standards, but the value of offset credits may also differ depending on the respective standard. The BNEF State of the Voluntary

¹⁴ <http://www.cdmgoldstandard.org/our-projects/project-pipeline>

¹⁵ <http://v-c-s.org/who-we-are>

Carbon Markets 2012 report contains an overview of the voluntary carbon market and provides indicative pricing estimates for different standards.¹⁶

4.1.4. METHODOLOGIES

Livestock methane capture and utilization is an established technology under the UN Clean Development Mechanism, and several approved methods exist to calculate emission reductions and assess additionality for both the capture and utilization of biogas from livestock manure projects.

- ACM0010 for the installation of manure management systems¹⁷
- AMS-III.D for small-scale projects that yield less than 60,000 tonnes of emission reductions per year¹⁸
- AM0073 for projects that collect manure from multiple sites for treatment in a central plant¹⁹
- AMS-III.R for methane recovery in agricultural activities specifically at a household/small farm level²⁰

4.1.5. EXISTING LIVESTOCK MANURE PROJECTS

There are currently 224 individual projects in the global CDM project pipeline to capture methane from livestock manure. Although only 957,000 CERs have been issued to livestock manure CDM projects to date, the project pipeline is estimated to generate almost 7 Mt of emission reductions per year through 2025.

There are currently 224 individual livestock manure methane capture projects in the global CDM project pipeline, with the potential to produce 7 million CERs/year.

The approved CDM methods tend to overestimate the volume of CERs that a project will generate because projects often encounter technical challenges the manure feedstock can be of variable quality, leading to under-performance. CERs are verified ex post facto, so eventual issuance often falls short of initial estimates. The difference between real emission reductions and those estimated using approved methods is referred to as the “yield” of a project. To date, livestock manure CDM projects have achieved an average yield of 42 percent (for 957 kilo tonnes of CERs) compared to initial estimates. Extrapolating to all 224 livestock methane CDM projects means the existing pipeline will generate 2.9 Mt of CERs per year, instead of the 7 Mt/year anticipated.

¹⁶ http://www.ecosystemmarketplace.com/pages/dynamic/resources.library.page.php?page_id=9184§ion=library&eod=1

¹⁷ <http://cdm.unfccc.int/methodologies/DB/FP0LYUJJMH0CE6O4KLG8PC24XXPEXF>

¹⁸ <http://cdm.unfccc.int/methodologies/DB/3EN93QEIQXUOEVRV0DRTIEF3Z5SDH>

¹⁹ <http://cdm.unfccc.int/methodologies/DB/2N19WQ6DCXNYRNJVZQQOHG7TK0Q2D8>

²⁰ <http://cdm.unfccc.int/methodologies/DB/JQHRMGL23TWZ08IT6G7GIRZ63GMI BZ>

FIGURE 9: NUMBER OF MANURE BIOGAS CDM PROJECTS

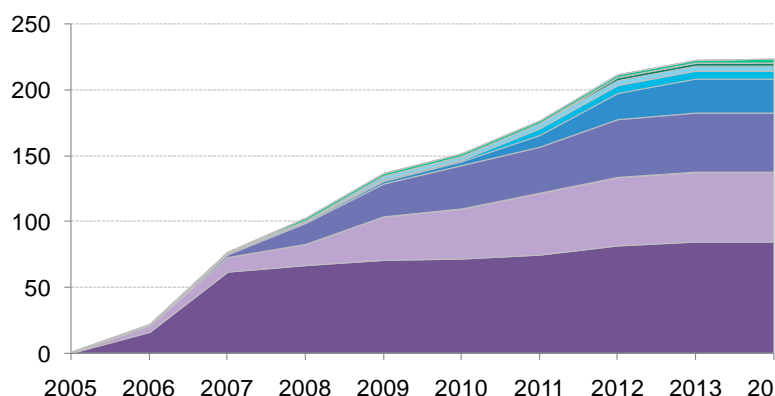
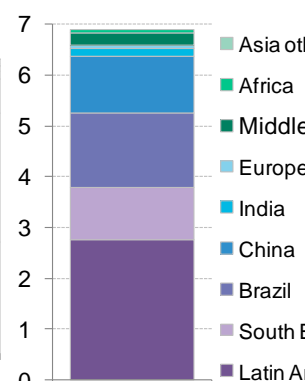


FIGURE 10: ESTIMATED MT CERS PER YEAR



Source: UNFCCC, Bloomberg New Energy Finance.

The majority of livestock manure projects are in Latin America (mainly Mexico), Brazil, Southeast Asia (mainly the Philippines), and China.

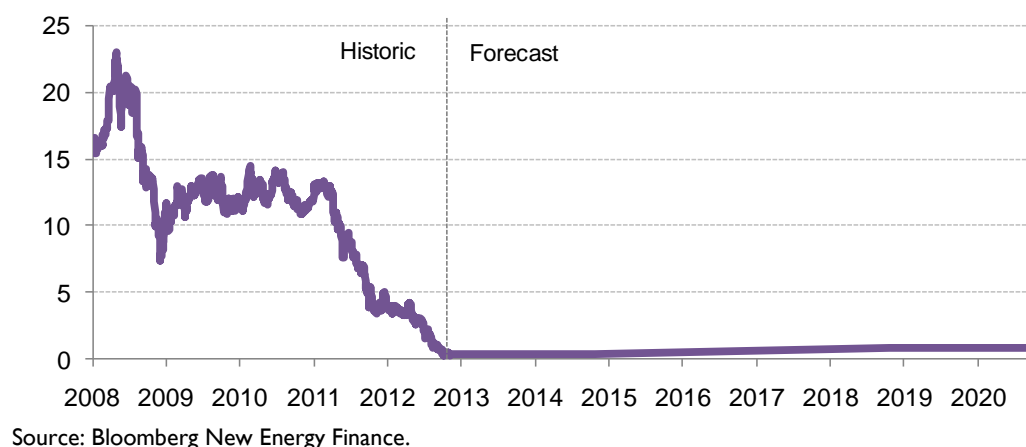
There is currently only one large-scale manure CDM project in Vietnam.

In addition to the SURE project, MARD is pursuing CDM approval for a program of activities (PoA) for household-scale biogas capture and utilization (see Section 3.1). CDM PoAs generate CERs in the same way as individual CDM projects, but a PoA allows for numerous individual projects to qualify for CDM status so long as each project can show that it conforms to a set template with defined additionality. The MARD PoA has not yet been approved, but if it is, it would allow for much easier access to CDM support for household-scale biogas projects in Vietnam. The administrative costs and level of expertise needed to qualify each project for CDM status would be significantly reduced under a PoA. The MARD PoA is also applying for Gold Standard accreditation.

4.1.6. CER PRICE AND OUTLOOK FOR NEW PROJECTS

The CER futures price for the front-year December contract has fallen by 99 percent since it reached a high of €23/t on 7 July 2008. Currently trading at €0.30-0.50/t, the CER market is in a state of chronic oversupply. This excess supply has resulted from a rapid increase in the number of projects over the past 2 years and a fall in European carbon prices. For example, the EU ETS has been the biggest buyer of CERs to date and have caused the long-term outlook for CERs to deteriorate significantly (Figure 11).

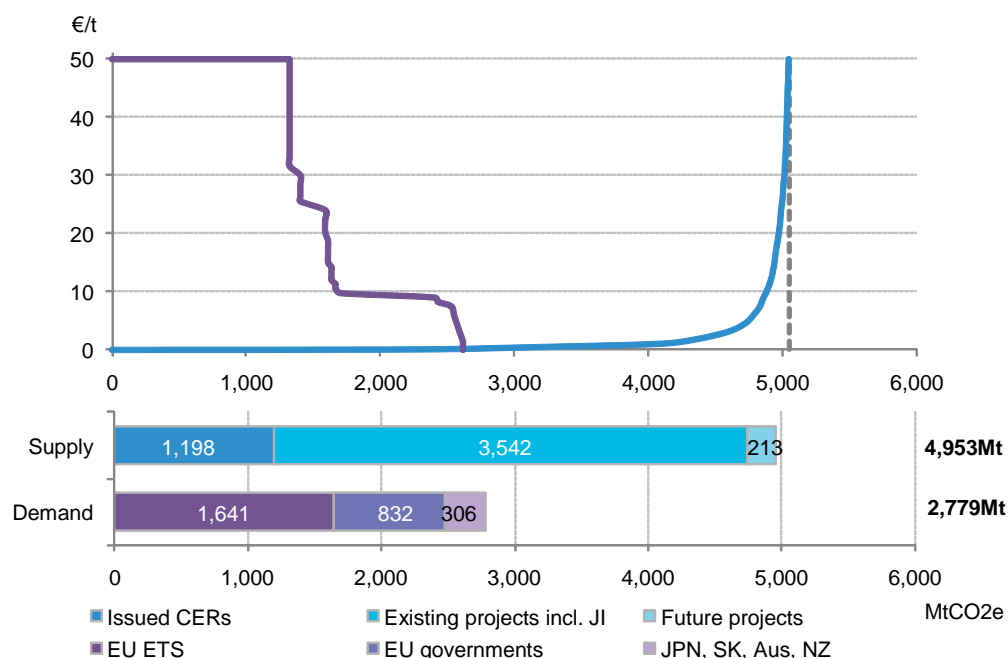
FIGURE 11: FRONT-YEAR CER PRICE TRADED ON THE INTERCONTINENTAL EXCHANGE AND BNEF SPOT PRICE FORECAST (€/TCO₂E)



Demand for UN offsets in the EU ETS is limited to 2020 to approximately 1.6 Gt due to constraints set by the European legislation. Demand from other sources, such as governments, is highly uncertain in the absence of an international agreement. Meanwhile, the CER supply pipeline has continued to grow and the market is currently oversupplied by at least 2 Gt through 2020 (Figure 12). Consequently, nominal price projection for CERs is €0.39–0.90/ton of carbon equivalent for the next 7 years unless demand and supply change significantly.

Our nominal price projection for CERs is €0.39-0.90/t of carbon for the next 7 years

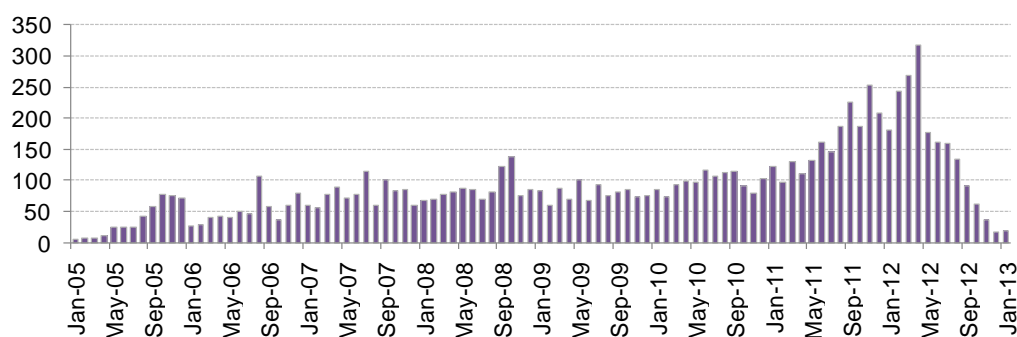
FIGURE 12: UN OFFSET SUPPLY AND DEMAND BALANCE FOR 2008–2020



Source: Bloomberg New Energy Finance. JI = Joint Implementation (under the Kyoto Protocol).

Since the CER price has fallen, the number of new CDM project submissions has also declined. In January 2013, 18 new projects began the CDM approval process, the lowest monthly number of new project initiations since 2005 (see Figure 1).

FIGURE 13: NUMBER OF NEW CDM PROJECTS BEGINNING THE APPROVAL PROCESS EACH MONTH



Source: Bloomberg New Energy Finance.

The number of new projects initiating the CDM approval process is expected to remain at its current low level. The incentive for projects to pursue CDM status has been eroded by the state of the oversupplied market. Consequently, it is increasingly difficult for developers to justify the upfront and ongoing administration costs of CDM registration and CER issuance at current market prices.

At present, carbon finance should not be considered an enabling driver for further growth of the Vietnamese livestock methane sector. This prospect may change over the next few years provided that the CDM oversupply situation is resolved, either by removing a large number of projects from the pipeline or increasing demand for CDM credits. However, this would require a radical alteration of the program that it is unlikely to happen before 2015.

Carbon finance should not be considered an enabling driver for further growth of the Vietnamese livestock methane sector.

4.2. OTHER SOURCES OF FINANCE

In addition to carbon finance, livestock methane capture and utilization projects in Vietnam are likely to be eligible for financial assistance from relevant bilateral or multilateral aid programs. *Climate finance* refers to equity, loans, guarantees, subsidies, grant funding, or other forms of concessionary finance for climate change mitigation and adaptation projects. The bulk of climate finance originates from developed country government aid budgets and is channeled through bilateral programs and multilateral development organizations such as the World Bank or other regional development banks. Access to specific sources of climate finance may be restricted to certain locations, technologies, or applications, but livestock methane recovery and utilization is likely to apply to a large number of initiatives that focus on energy generation, agriculture, waste management, and pollution control.

Developed countries have pledged \$100 billion of climate finance²¹ per year by 2020 through the UNFCCC framework.²² An additional \$33 billion in “fast-start finance” has been pledged over the past 3 years.²³ The Green Climate Fund established by the UNFCCC in 2010 is also likely to become an important intermediary in the delivery of climate finance²⁴. However, the total funds listed above are unlikely to fully materialize.

More than \$200 million of climate finance has been committed for greenhouse gas mitigation in Vietnam, according to the most recent national communications to the UNFCCC.²⁵ There are 14 fast-start finance initiatives in the country funded by Germany, the UK, and the Netherlands. Notably, the Netherlands Government considers the MARD household-scale biogas project to be a fast-start finance initiative.²⁶

²¹ The \$100 billion/year may come from a “wide variety of sources, public and private, bilateral and multilateral, including alternative sources,” and it is not envisaged that \$100 billion of direct aid will be deployed each year.

²² <http://cancun.unfccc.int/>

²³ http://pdf.wri.org/climate_finance_pledges_2012-11-26.pdf

²⁴ <http://gcfund.net/home.html>

²⁵ <http://www3.unfccc.int/pls/apex/f?p=116:23:2021619736122092::NO::>

²⁶ <http://www3.unfccc.int/pls/apex/f?p=116:13:83929730062160>

The regional development banks, such as the ADB, are also an important source of concessionary finance for low-carbon investment in Vietnam. The ADB has provided a \$95 million loan to the MARD project and is also funding the Low Carbon Agricultural Support Project with a \$74 million loan approved in December 2012.²⁷ The initiative specifically aims to support livestock methane capture technology in Vietnam with more than 36,000 small, medium, and large-scale biogas plants expected to be built by 2018.²⁸

²⁷ <http://www.adb.org/projects/45406-001/main>

²⁸ <http://www.adb.org/news/viet-nam/adb-funded-biogas-plants-tackle-viet-nams-growing-rural-waste-threat?ref=countries/viet-nam/news>

5. CONCLUSIONS AND RECOMMENDATIONS

The technology for capture and use of biogas from livestock waste for electricity is present in Vietnam and there is significant potential to scale up the number of household- and farm-scale biogas digesters. The current household-scale capacity is around 70 MW, while the total technical feasible (but not necessarily economically viable) capacity for electricity generation could be as high as 2.6 GW assuming 2013 manure production levels on farms.



The viability of livestock biogas for electricity generation is dependent on the cost of feedstock, the markets for by-products, the capital costs, and government FiTs. The economics of a livestock methane capture and utilization project are closely linked to its size and capacity. Household-scale installations are unlikely to be a viable commercial investment opportunity for electricity generation due to high initial capital outlay and undefined, inconsistent returns. Farm-scale installations can potentially offer financial returns sufficient to attract private investors, but high upfront project costs and developer inexperience are likely to present a significant barrier to private investment.

Experience in Europe suggests that larger-scale digesters have capital costs on the order of \$4-5 million/MW. However capital costs in Southeast Asia tend to be lower -- \$2.5-3.7 million/MW for small projects below 1 MW. Because of economies of scale, larger projects can have capital cost \$1.2-1.3 million/MW for the least expensive projects of 1.5-3.0 MW. The only Vietnam project with published capex costs \$2.2 million for a 2 MW project. The capital costs for other electricity sources, such as solar, wind, natural gas, and coal, tend to be \$1-2 million/MW.

This report focuses on electricity generation, but there is already a small-scale market for heating and cooking with biogas.

Other renewable energy sources may be more competitive for electricity generation in Vietnam without additional finance. For a typical farm-scale 1 MW biogas facility, in the absence of any feedstock costs, the LCOE range for biogas (\$69-87/MWh) exceeds the average LCOE for solar, wind, biomass, small hydropower, and geothermal in Vietnam and the wholesale electricity price of \$54/MWh, which appear more economically attractive but do not help resolve Vietnam's manure over supply problems.

If the Government of Vietnam wants to scale up livestock biogas for electricity generation, then there is a significant need for finance, technical assistance, education, and legal and regulatory support. Financing would be needed to close the gap between the LCOE of electricity for farm-scale biogas and the wholesale price of electricity. This could take the form of capital grants or subsidies, feed-in tariffs, or new international climate finance (e.g., Green Climate Fund) and internal rates of return of 10 percent would be needed to elicit private investment interest. Existing carbon finance, such as the CDM, is unlikely to be a catalyst for growth of the technology. The value of digestate as a fertilizer and soil conditioner is another important financial factor, and it is useful that the GVN help to develop markets for these products if proven to be economically viable.

Capacity development is needed on several fronts. A lack of experienced and skilled workers in the construction, operation, and maintenance of biogas plants is delaying the development of the sector, and access to after-construction service, spare parts, and equipment is limited. Awareness raising on the benefits of biogas digesters, including the uses of digestate for a proven domestic market, is necessary as well as training and education on operation and maintenance of the systems.

There are co-benefits of livestock biogas capture and use. Increasing the number of biogas digesters could have positive impacts on rural development in Vietnam especially the removal of excess manure on farms and reduction of methane releases to the atmosphere. In 2011, 69 percent of the population lived in rural areas and 48 percent of employment was in agriculture, which contributed 22 percent of GDP.²⁹ The development of biogas could enhance rural employment and increase farm income, but other renewable energy technologies might also provide equal if not higher livelihood and employment benefits. This report focuses on the farm level, but at the household level, gathering traditional fuels (wood, charcoal, agricultural residues, and dried animal dung) is time intensive, particularly for women and children. Small-scale biogas units can provide fuel for heating and cooking, thereby freeing up labor for more productive, income-generating activities. Importantly, shifting to biogas could result in health benefits associated with improved air quality.

Livestock biogas is specifically identified in Vietnam's Green Growth Strategy. Biogas is specifically mentioned in Vietnam Green Growth Strategy as an activity to reduce greenhouse gases in agriculture by the treatment and reuse of by-products and waste from agriculture production.³⁰ While this is not necessarily the most economically optimal use, additional environmental valuation of such co-benefits (environmental, health, water, sanitation, employment) is needed to weight the subsidization of biogas over alternative renewable or non-fossil fuels in the country. Biogas technology falls under the

²⁹ <http://databank.worldbank.org/data/home.aspx>

³⁰ <http://lowemissionsasia.org/content/vietnams-national-strategy-green-growth>

strategic task of “greening production,” which specifically mentions “green agriculture based on environmentally friendly structures, technologies and equipment.” Besides the climate change mitigation benefits, biogas digesters are a more environmentally friendly method of disposing of livestock waste.

ANNEX A: LIVESTOCK METHANE CDM PROJECTS

TABLE 4: TOP 20 CARBON CREDIT BUYERS WORLDWIDE BY AMOUNTS THROUGH 2012

Credit Buyer	Total Credits Through 2012 (ktCO₂e)	Total Credits Through 2020 (ktCO₂e)	Number of Projects
Agcert	4,701	8,795	54
Cargill / EcoSecurities	1,572	2,834	29
Luso Carbon Fund	1,022	6,267	13
Marubeni	666	1,808	2
Trading Emissions	602	3,151	15
Danish Ministry of Climate & Energy	346	716	3
Bunge	329	1,043	2
Consortium (Belgium, Canada, Denmark, Luxembourg, Spain)	244	664	1
EcoSecurities	214	528	11
Equity Environmental Assets Ireland	185	587	8
BGP Engineers	151	405	3
Statkraft	147	407	1
South Pole Carbon Asset Management	120	597	1
Netherlands Clean Development Facility	114	574	1
Ecolutions / Gazprom Marketing & Trading	105	1,329	3
ITOCHU Corporation / DOWA Ecosystems	104	743	2

Source: Bloomberg New Energy Finance, UNFCCC.

TABLE 5: TOP 20 COUNTRIES FOR CARBON CREDITS THROUGH 2012

Country	Total Credits Through 2012 (ktCO₂e)	Total Credits Through 2020 (ktCO₂e)	Number of Projects
Mexico	5,828	16,917	80
Brazil	3,590	14,245	45
China	1,538	10,276	26
Philippines	1,438	6,770	43
Thailand	473	1,989	6
India	215	1,419	6
South Africa	206	728	3
Chile	152	7,752	4
Cyprus	151	405	3
Israel	140	1,997	2
Indonesia	105	188	1
Vietnam	90	821	1
Ecuador	50	446	1
Serbia	47	369	1
Cambodia	23	68	1
Singapore	0	234	1

Source: Bloomberg New Energy Finance, UNFCCC.